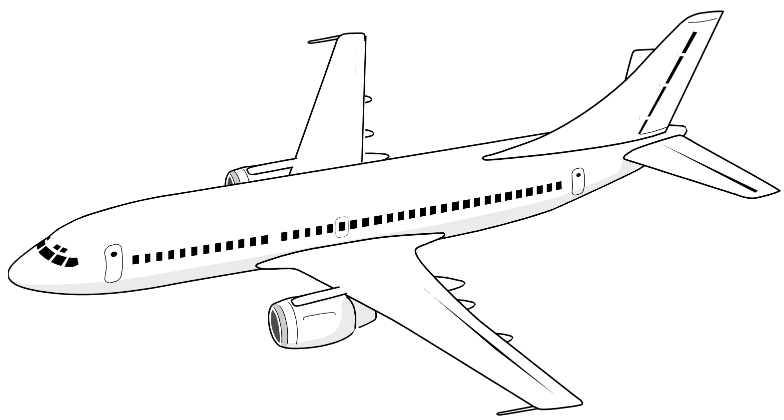
FAA AIRWORTHINESS ASSURANCE
NDI VALIDATION CENTER

FY02 Project Summaries



Prepared by:

The FAA AANC at Sandia National Labs

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List of Projects

AANC FY02 Project Summaries

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Aircraft Composite Inspections and Reference Standards

Dennis Roach and Kirk Rackow
Sandia Labs FAA AANC

Due to the potential weight and associated cost savings, the use of composites on commercial aircraft continues to grow. The capabilities of inspection techniques to detect flaws in composite structures should keep pace with this expanding usage since inspection is a critical element in assuring their continued airworthiness. This project is addressing the need to introduce additional NDI for composite structures and is establishing the sensitivities and limitations of potential NDI methods. The activates are carried out in concert with the AANC's membership in the SAE Commercial Aircraft Composite Repair Committee (CACRC) Inspection Task Group. The CACRC is an international committee consisting of composite experts from the airlines and aircraft manufacturers. The AANC now co-chairs the Inspection Task Group.

<u>Composite Inspection Reference Standards</u> - One phase of this effort continues to develop composite reference standards and is assessing improvements in composite inspections through their use. Currently, the recognized number of construction variables makes the potential number of standards very large and unmanageable. In an effort to keep the required number of composite calibration standards manageable, the AANC worked closely with the CACRC to define specifications for a minimum set of honeycomb and composite laminate calibration standards for damage assessment and post-repair inspection of those composite structures. For non-metallic honeycomb structures, an initial set of variables was identified which resulted in the fabrication of 64 unique honeycomb panels, each possessing combinations of the identified variables that bound most existing conditions found in service. NDI tests determined that certain construction variables affected the outcome of the NDI inspections more so than others. By identifying these variables, the team was able to design a smaller subset of standards using only those variables that truly impact NDI, thus eliminating unnecessary standard configurations. A series of subsequent tests determined that the minimum honeycomb reference standard set was able to fully support inspections over the full range of honeycomb construction scenarios encountered in the field. For solid composite laminates (thick skins with no honeycomb), the FAA-AANC/CACRC team identified G11 Phenolic as a generic laminate material that sufficiently replicates certain material properties found in carbon graphite and fiberglass solid laminate structures. Comparisons of resonance testing response curves from the G11 Phenolic prototype standard were found to be very similar to the resonance response curves measured for carbon and fiberglass laminates. The G11 material improves on existing solid laminate standards because it is inexpensive, can be consistently manufactured, and is easily machined into laminate thickness standards. The reference standards include typical composite flaw scenarios - delaminations, disbonds, and inclusions/porosity - and incorporate structural configurations of Boeing, Douglas, Airbus, and Fokker aircraft. At this point, the primary standards have been designed and adopted. As a result of this project, two SAE Aerospace Recommended Practice (ARP) documents, ARP 5605 and ARP 5606 for honeycomb and solid laminate reference standards, respectively, were developed and adopted for

publication. We are now investigating the need to add new standards to accommodate secondary construction variables.

An Experiment to Assess Flaw Detection in Composite Honeycomb Structures - The second major activity is studying both human tap tests and NDT equipment that has recently been introduced to automate/improve inspections on honeycomb structures. This activity will quantitatively assess the performance of several inspection methods used to detect voids, disbonds, and delaminations in adhesively bonded composite aircraft parts. While acoustic tap testing and automated tap testing are the initial focus of this effort, other composite inspection techniques such as low/high frequency bond testing, through-transmission and pulse-echo ultrasonics, thermography, and mechanical impedance analysis will be applied to complete a comprehensive assessment of flaw detection in composite structures. In addition to conventional NDI, the application of advanced NDI techniques such as air-coupled ultrasonics, thermosonix, and scanning UT is being evaluated. Field testing involves a blind Probability of Detection (PoD) study in which the experiment is traveling to airlines, third party maintenance depots, and aircraft manufacturers to acquire flaw detection data. To date, 34 experiments have been completed at 12 different airlines. Twenty-five airline and repair stations have volunteered to take part in this experiment over the next year.

Finally, a third activity will be initiated this year to address inspection of thick laminate structures. The increasing use of thick laminate composites coupled with the realization that new inspections need to be added to laminates on aging aircraft, has highlighted the need to investigate applicable NDI methods. This effort will attempt to make general strides in inspection of thick laminate structures containing complex geometry. Specific aircraft structures will be selected to provide realistic inspection scenarios. Preliminary testing in the first year may lead to a focused POD study for these structures. The overall goals of this project are to produce optimized reference standards, associated R&D data, and performance assessments of advanced NDI methods to improve inspections on composite structures.

Implementation of New Inspection Techniques for Flaw Detection on Commuter Aircraft

Kirk Rackow
Sandia Labs FAA AANC

Most carriers have always used the latest NDI technology as a routine part of their inspection procedures to help extend the service life of their planes. In contrast, commuter aircraft are still inspected primarily through various visual methods, which may be difficult to perform, or which are subject to different interpretations. In addition, these techniques provide no capability for detection of sub-surface flaws or other areas that cannot be visually inspected. The object of this program is to continue with activities related to NDI problems in the commuter industry, especially new inspection requirements.

The current NDI project, Fairchild Metro lower wing spar inspection is being completed with the end result being the integration of the new eddy current and ultrasonic inspection procedures being integrated into the SID (Supplemental Inspection Document) for the Fairchild SA226 and SA227 aircraft. The final field tests of the eddy current procedure have been completed at Perimeter Aviation in Canada. The actual inspection procedure (eddy current) was used to inspect five different aircraft and in turn provided some feedback concerning the use of the inspection procedure. The feedback has been integrated into the procedure, which should improve the inspectors understanding and use of the procedure. The final AANC version of the procedures has been sent to Fairchild. The last step of this process after the SID integration is to have a presentation/workshop showing the operators and maintenance personnel these procedures in use.

New project areas are being discussed with OEM's (Raytheon & Cessna) to determine specific problem areas that would be the greatest benefit to the commuter industry. Base on OEM input, we are currently evolving tasks in the following major activity areas. The first area involves a composite inspection effects-of-defects study that will relate the void content (porosity) and associated NDI findings (attenuation measured in Db or % of full screen height) to residual strength of a composite structure. This approach will quantify the effects of various defects and establish allowables for voids/disbonds/delaminations in their aircraft structures. Another area addresses corrosion detection. This would involve evaluating and testing new and existing technologies and determining the best possible technique based on the analyzed results. A third area is in crack detection in a multi-layered structure similar to the Fairchild wing spar. We may try to adapt the inspection techniques used on the wing spar and apply it to a new structural configuration. The goal of the project will be the development and documentation of a specific NDI procedure addressing the identified problem areas. Products of this project will be experimental data, assessments of NDI methods for the commuter industry and formal adoption of improved maintenance/inspection practices. Final inspection procedure documentation should be reviewed for consideration as formal Original Equipment Manufacturer's NDI procedures at the end of the project.

Assessment of Composite Laminates and Associated NDI for Rotorcraft Components

Dennis Roach
Sandia Labs FAA AANC

The primary focus of this activity is to assure proper FAA oversight for utilization and in-service inspections of rotorcraft structures. The use of damage tolerance analysis (DTA) to direct and improve rotorcraft maintenance practices is being addressed as is the related use of nondestructive inspections to manage helicopter safety. Overall project formulation with RITA, TOGA, Army, Navy, Bell Helicopter, Boeing and Sikorsky Aircraft will continue to be matured. The primary goal of this project is to improve the producibility, inspectability, serviceability, and cost effectivity of rotorcraft components.

<u>Rotor Hub Damage Tolerance and Inspection</u> - One portion of this project is integrating a series of nondestructive inspections into generic subelement fatigue tests of composite main rotor hubs. The tests are assessing NDI sensitivities with respect to typical flaws. Test results are also be used to validate promising flaw growth prediction methods and to establish safe inspection intervals. Successful fatigue test have already been completed in previous phases of the rotor hub effort. The relationship between rotor hub damage tolerance and flaw detection capabilities has been clearly established. We are in the final phase of fatigue testing. The NDI, fatigue performance, damage tolerance, and modeling to ensure safe inspection intervals will be completed in the coming year.

Corrosion Detection in Multi-Layered Rotorcraft Structures - The second major segment of this effort is addressing the integration of more sophisticated NDI into routine rotorcraft maintenance. There is a need to nondestructively evaluate airframe structures in order to recognize and quantify corrosion before visual indications are present. Industry lacks the necessary data, techniques, and experience to adequately perform routine corrosion inspection of rotorcraft. Probability of detection (POD) specimens have been produced that simulate two lap joint configurations on a model TH-57/206 helicopter. The FAA's Airworthiness Assurance Center at Sandia Labs and Bell Helicopter have developed dual frequency eddy current (EC) techniques to inspect these test specimens. It allows users to distinguish between corrosion signals and those caused by varying gaps between the assembly of skins. Complete helicopter test beds were used to validate the laboratory findings. Inspection procedures and training materials were produced. Beta site evaluations of the dual frequency eddy current method for corrosion detection will continue at Petroleum Helicopters and Bristow Helicopters. Final procedure development and formal adoption of this NDI method via OEM manual revisions is also underway.

Crack Detection in High Cycle Fatigue Joints for Rotorcraft Applications - A new NDI activity is investigating small crack detection problems experienced in high-cycle fatigue areas such as tail booms and transmission assemblies. Nondestructive evaluations of rotorcraft airframes face inherent problems different from those of the fixed wing industry. Most rotorcraft lap joints are very narrow, contain raised fastener heads, may possess distortion, and consist of thinner gauge material thickness. In order to address these inspection challenges, a program was initiated to validate the use of eddy current inspection methods on specific rotorcraft lap joints that experience high-cycle, vibratory fatigue loading. Probability of Detection (PoD) specimens have been produced that simulate various crack configurations in simulated tail boom structures. In this study, a wide array of eddy current (EC) techniques were deployed to blindly inspect the test specimens. The test results showed enough promise to justify beta site testing of the eddy current methods evolved in this study. Near-term activates will focus on field evaluations using rotorcraft inspectors. Issues such as training, procedures, and beta-site data acquisition will also be addressed.

Liquid Penetrant Technology Support

David Moore
Sandia Labs FAA AANC

This project continued to characterize the variables that affect liquid penetrant inspection using low cycle fatigue cracks in titanium alloys. Test samples include specimens characterized by Wright Labs, as well as, a set of specimens developed in cooperation with the Air Force Research Labs. Cleaning experiments using the titanium test samples continued this year. AANC assisted the Air Force in their liquid penetrant reliability study. This study is characterizing the factors that influence the inspector's detection ability. AANC's role in the program is to help design and manufacture the sample set and aid in the collection of the data. The lessons learned from this Air Force study will assist the AANC in future program years. AANC procured a large ultrasonic cleaner to aid in the inspection of large rotating engine parts.

AANC is currently undertaking the experimentation and validation of cleaning techniques for aircraft manufacturers prior to fluorescent inspection. A series of experiments on industrial cleaners is currently being conducted in the Fluorescent Penetrant Inspection Laboratory. The specimens are titanium-based alloys from a Pratt and Whitney JT-8D engine. The disassembly of the engine has been a large cost for the current project year. All engine modules have been completely disassembled. The key to the inspection process is clean dry components. A project is underway to ensure that the engine components to be inspected are clean and free from any contamination. A test matrix consisting of several common cleaners used by industry, as well as common aircraft contaminants, such as fuel and oil are being studied. The interaction of the cleaners and the inspection process is completed. The effectiveness of each cleaner in removing a given contaminant will be documented and chemical analysis of the effectiveness will be reported at the SAE Committee K meeting at the Fall ASNT Conference.

Detection of Faying Surface Corrosion Study

Mike Bode
Sandia Labs FAA AANC

It has been recognized by both the FAA and the aviation industry that the National Aging Aircraft Research Program (NAARP) has produced a number of potentially beneficial NDI techniques. Further, these new techniques should be evaluated and ranked in order to expedite their integration into aircraft maintenance hangars. These NDI assessments will also assist the FAA Hughes Technical Center in: 1) directing NDI technology to pertinent inspection applications, and 2) categorizing and funding NDI methods for development and/or validation activities as appropriate. The purpose of this experiment is to assess the ability of conventional and emerging NDI techniques to inspect for hidden surface skin corrosion. The ultimate goal is to establish a baseline (i.e. how well are we doing now) and to transfer improved NDI techniques to aircraft maintenance hangars. In this effort, the AANC has implemented structured NDI Validation Experiments directed towards Detection of Hidden Faying Surface Corrosion in Aircraft Skins.

The final phase of data analysis from the initial study is nearing completion. Results will be presented at the 6th Joint FAA/DoD/NASA Aging Aircraft Conference. Natural corrosion specimens have undergone extensive characterization and discussions are underway with the National Research Council of Canada Institute for Aerospace Research pertaining to the reassembly of these panels as specimens that incorporate multilayer corrosion, and their use in validating holistic life prediction methodologies. Array eddy current technologies are being scheduled for corrosion detection evaluation in the fall of 2002 with additional plans to re-evaluate pulsed eddy current technologies in the following calendar year. While pulsed eddy current methods were evaluated in the original structured experiment, the participating organizations have made rapid progress in developing their technologies and have expressed intentions of repeating the experiment with upgraded capabilities. Additionally, technologies that were not included in the original study should be evaluated as they show promise of either increasing the speed of the inspection process and/or the detection capabilities. Other candidate inspection methods still being developed require additional assessment using the structured corrosion experiment. Candidate technologies include, remote-field eddy current methods, photon induced positron annihilation (PIPA) methods and high-speed digital radiography methods. A search for heavily pillowed specimens will also be conducted in 2003.

The Boeing NDT group has expressed very strong interest in parametric studies of the ability of digital radiography to detect and quantify corrosion, especially interfacial corrosion where the corrosion product is present. Additionally, they have expressed a desire to work towards a better understanding of how corrosion causes stress in skin layers that can reduce the life span of the structure. With this in mind we are proposing a continuation of the Structured Corrosion Experiment with three basic goals: 1) Continue assessment activities using the Structured Corrosion Experiment. 2) Develop specimens using natural corrosion panels. 3) Develop new specimens and capabilities for implementation of Holistic Life Prediction Methodologies (HLPM). The tasks will include: 1) maintain the current set of engineered corrosion panels for use in further assessments of corrosion detection capabilities, 2) reassemble the natural corrosion panels with corrosion product in place for use in evaluating the capability of digital radiography to detect hidden faying surface corrosion; include substructure where appropriate and simulate inspections from the interior of the aircraft, and 3) acquire and characterize natural corrosion specimens with heavy pillowing from corrosion; use this information to gain insight into the usefulness of this technique for implementing the Holistic Life Prediction Methodology proposed by Kinzie and Peeler (1999) at the Third Joint Aging Aircraft Conference.

Bolt Hole Crack Detection Study

David Moore
Sandia Labs FAA AANC

The goal of this program is to quantify the reliability of meter and impedance plane instruments while conducting fastener hole crack inspections in multi-layered aluminum structures. This program was suggested by Boeing Commercial in response to problems experienced in the field. The primary difficulty is in obtaining the correct depth (i.e. skin of interest) for the bolt hole inspection device to operate. This difficulty is exaggerated in configurations where the stack-ups involve thin skins of 0.040" thick or less. This program is broken down into three phases: the planning phase, manufacturing phase and the implementation phase (Probability of Detection experiment). The planning phase was conducted in the first year of the project. A survey has been conducted by calling several eddy instrument users. The survey results: instrument, probe selection and scanner are still under review. A test matrix to show the array of probes and instruments to use in the experiment is currently being assembled. Test specimens design and experiment protocols are in the preliminary stage. During the second year, the test specimens will be manufactured. The implementation phase will be started in the second year and completed in outlying years of the project.

Use Of Composite Doublers To Repair Aircraft Structures

Dennis Roach
Sandia Labs FAA AANC

Completed and ongoing AANC/FAA studies have confirmed that under proper conditions, composite doublers can provide a safe, damage tolerant, and potentially low cost aircraft repair. The project results have provided data regarding the damage tolerance capabilities of composite doublers, specific design certification and validation of inspection techniques. This effort continues to validate the full array of engineering issues ranging from design to in-service surveillance. A major emphasis of the project is to streamline the design-to-installation process in order to make composite doubler technology more attractive for wide scale use. Peripheral activities are addressing proof-of-concept testing to support niche applications of the composite doublers on other aircraft in the Boeing family. Boeing-Long Beach and Federal Express teamed with the AANC to design, analyze, and develop inspection techniques for an array of composite doubler repairs. The general DC-10 repair areas which provide a high payoff to FedEx and which minimize design and installation complexities have been identified as follows: 1) gouges, dents, lightning strike, and impact skin damage, and 2) corrosion grind outs in surface skin. Structural tests evaluated the damage tolerance and fatigue performance of composite doublers while finite element models were generated to analyze the DC-10 doubler designs. Validation efforts for the DC-10 inspections revealed that ultrasonic resonance and pulse-echo (dual-element pitch/catch mode) test methods work well in detecting flaws and mapping out flaw shapes in composite doublers. A Probability of Detection (PoD) study using airline inspectors produced a 90% PoD for flaws that were half the size of the required detection threshold. Technology transfer and performance assessment of the pitch-catch ultrasonic inspection technique, recently incorporated into the Boeing NDT Standard Practices Manual, continues.

The associated Pilot Program was successfully completed in January 2002 to produce the required number of field repairs on FedEx DC-10 aircraft. As composite doubler repairs gradually appear in the commercial aircraft arena, successful flight operation data is slowly being accumulated. Periodic inspections, that will continue over the life of these repairs, have not revealed any flaws in the composite doublers. In addition, the new Sol-Gel surface preparation technique was evaluated. Fatigue coupon tests produced Sol-Gel results that could be compared with a large performance database of repairs installed by conventional means. We are continuing the FedEx Pilot Program beyond the minimum requirements in order to compile performance history on composite doublers installed by the Sol-Gel method. This will allow us to lead the aviation industry in getting this faster and cheaper surface preparation method approved. The commercial aircraft repairs are not only demonstrating the engineering advantages of composite doubler technology but are also establishing the ability of commercial maintenance depots to safely adopt this repair technique.

Related activities are producing approved material allowables for Boron-Epoxy. The DC-10 Structural Repair Manual is being formally modified to include composite doubler repairs. This represents a major milestone in the evolution and wide-scale use of composite doublers. Project tasks are also producing documentation to allow the FAA to properly direct the use of this technology. An FAA Advisory Circular is being prepared to delineate the training, procedures, design guidelines, quality assurance, and inspections required for a maintenance depot to utilize this technology. This project will also establish a national training infrastructure to facility technology transfer. Finally, inquiries received from other airlines (American, United, US Airways, Delta), maintenance depots, and OEMS (Boeing-Seattle, Raytheon) are being addressed. The AANC will help pursue applications and emphasize technology transfer initiatives in order to help the aviation industry independently and safely adopt composite doubler technology.

Technology Transfer of Infrared (IR) Detection of Ultrasonically Excited Cracks

Mike Ashbaugh
Sandia Labs FAA AANC

This activity seeks to utilize IR imaging to detect cracks. The technique uses high-power ultrasonic excitation as its heat source. Preliminary research at Wayne State University (WSU) has resulted in promising developments. Over the years as part of the FAA's Inspection System Research Program, pulsed thermography has been shown to be able to detect disbonding and corrosion thinning in aluminum aircraft fuselage skins. Its ability to detect cracks has been explored but until recently the relatively small field of view required to find small cracks was thought to preclude its usefulness as a viable alternative to other NDI methods such as eddy current. Researchers at WSU have demonstrated in a preliminary fashion the ability for infrared cameras to detect heat given off by cracks when stressed acoustically or ultrasonically. The apparent advantage of this method is its ability to view larger inspection areas and image even small cracks with very high signal to noise ratios. Since the undamaged area of a component is only minimally heated by the ultrasonic stressing, the resulting image of cracks are seen as bright features against a dark background field, thus providing the potential for detecting extremely small cracks with very high sensitivity.

Activities to date have focused on understanding the mechanism associated with heating of the cracks. Several tools have been utilized in this effort. Three different ultrasonic sources (the most recent being 40 kHz.) generating different frequencies have been acquired by WSU. WSU has also acquired a laser vibrometer in an attempt to measure the acoustic energy in the part being inspected. WSU has written an algorithm for processing the laser vibrometer data. The output of this program displays the magnitude of the vibrometer signal as a function of frequency and can gate selected time regions of the data output from the laser vibrometer. A program analyzing the acoustic wave moving through a cracked material has also been demonstrated. The US Air Force Research Laboratory is also working with WSU and the AANC on this technology. The AANC is providing an additional system for tests, test specimens for system development and will be involved in developing a test program for validation testing.

Validation and Technology Transfer of Pulsed Eddy Current

David Moore
Sandia Labs FAA AANC

The primary purpose of this project is to continue technology transfer activities in an effort to successfully implement a pulsed eddy current system in the field. AANC will participate with equipment/technique developers at Iowa State University, and leading researchers throughout the world to assist in equipment development. The second phase of this project will determine if pulsed eddy current can detect cracks in a DC-10 crown splice joint. This phase of the project will document the DC-10 inspection procedure and optimize the pulsed eddy current operating variables for this inspection. This stage of the project is currently underway. The probe design and equipment inspection variables have been documented for a DC-10 reference standard. AANC has procured an off-the-shelf manual scanning data acquisition system. This system has the ability to incorporate ultrasonic and eddy current inspection technologies. This system will be sent to an Original Equipment Manufacture (OEM) to add pulsed eddy current software. A vendor has been selected to supply several DC-10 aircraft sections. Structured experiments are being designed for this test method for future validation efforts. A set of DC-10 test specimens are being designed and fabricated to be representative of the inspection area and protocols are being written for data collection. Support activities for the field test phase will be provided by AANC.

NDI Capability Characterizations for Aircraft Inspections

Mike Bode
Sandia Labs FAA AANC

The currently funded program has an objective to use formalized AANC procedures for assessing capabilities of emerging NDI techniques short of full POD experiments. The results of this program are the early assessment of new or enhanced NDI technologies and the identification of the range of physical factors that potentially influence inspections. In this effort we continue to review and select candidate technologies and take them through a capability exercise. One of our additional goals was to acquire equipment that will allow for high-resolution characterization of defects (e.g. cracks) so that we may fabricate more realistic specimens from actual aircraft components. To this end, optical magnifying and imaging equipment has been purchased and is being used to characterize defective samples at the AANC.

Method specific experimental plans were developed for one emerging technology due to the unique way in which it works. Fatigue damaged samples were fabricated and sent to Positron Systems for their inspection by photon induced positron annihilation (PIPA). In another project the NASA/Foerster rotating eddy current probe has undergone a reliability assessment utilizing the inner layer crack detection panels. This assessment was more in depth than other studies because it was a continuation of prior assessments, but was appropriate to this task because new features had been added. The NASA technology incorporated a giant magneto resistive (GMR) element into the probe, and the Foerster Rivet Check product, which is commercially available, incorporates refinements in data filtering. Both technologies showed increased detection capabilities over previous versions, but still suffer from edge effects when the inspection site is too close to the lap splice edge. Also undergoing continuations of prior assessments is the JENTEK MWM GridStation system. This system has been purchased by the FAA and is currently undergoing evaluation in concert with efforts by Boeing NDT. Initial assessments showed an ability to detect inner layer cracks around fasteners of lap splice sections, but also showed a need for further development of the system software and formal operational procedures. The system will undergo formal quantitative evaluations this fall after final software and procedure upgrades are delivered.

Other NDI capability characterization efforts to evaluate remote field eddy current and digital radiography are planned for the near future pending efforts by the developers to refine their products. In response to concerns of the Aging Aircraft Working Group (AAWG), portions of this project will be focused on an effort to quantitatively evaluate the reliability of systems that are commercially available for detection of small cracks around fasteners in lap splice structures. As part of this effort we are working with Airbus, in addition to Boeing, to gather their input on appropriate structures and problems with those structures that should be included in the study. The final product of the capability characterizations will be in the form of short reports that can be added to the NDI Capabilities Characterization Catalog.

Visual Inspection Reliability - Characterizing Inspector Behavior and Decision Criteria

Caren Wenner
Sandia Labs FAA AANC

The Visual Inspection Reliability Program (VIRP) has thus far been composed of a series of visual inspection studies. The first study provided a baseline of visual inspection performance in commercial aviation, the second provided a baseline in commuter aviation, and the third addressed how instructions impact performance. The completed studies have suggested that there is a wide variability in how even experienced inspectors perform their inspection tasks. These studies have provided some insight into the relationships between inspection behaviors and inspection performance.

The previous studies have been designed to determine how some potential explanatory variables (e.g., work instructions, decision criteria) can account for this variability. However, it is expected that there are still many other factors impacting visual inspection performance that have not yet been addressed in the previous efforts. The fourth study will address inspector behavior and decision criteria. The first phase of this current work will attempt to characterize inspection behaviors in the inspectors' normal work environments. The inspectors who have participated in previous VIRP studies have indicated that the tasks they are asked to perform at the AANC are quite similar to those they perform in the course of their daily inspection duties. However, it is unknown how the behaviors exhibited by the inspectors during the VIRP studies differ from actual performance. Some of the questions of interest are: what types of search strategies are used, what is the typical numbers and types of defects identified, how are the instructions used, and what other information sources are used by the inspectors (and how are they used). This visual inspection reliability program will identify some other factor(s) that may impact visual inspection performance, and will include designing and carrying out a study to determine how these factors impact visual inspection.

The second phase of the current work involves the investigation of the decision criteria used by inspectors in making calls during a visual inspection. The results from the previous Visual Inspection Reliability Program studies suggest that, for some defects, inspectors are using different criteria to decide whether to call or not call a specific flaw. The OEM or airline documentation specifies specific criteria or standards for identifying flaws. This work will investigate how inspectors use these criteria for recognizing or identifying defects during a visual inspection. For example, can people recognize these standards when they see them, how (and how accurately) do people ensure that the standards are met, and how do facility differences impact their decisions. The results from this effort, in conjunction with the results of previous visual inspection studies, will help provide a better understanding of how to maximize visual inspection performance and will lead to recommendations that can be shared with industry.

Tire Retread Escalation

Roger Clough
Sandia Labs FAA AANC

Advances in tire technology and the introduction of radial tires into the aircraft fleet requires updated guidance for the inspection, maintenance, and operation of aircraft tires. Recent updates to the FAA's tire standards partially address the new requirements. However, the Advisory Circular 145-4 tire testing requirements were designed principally based on bias tire experience that is not relevant for radial tires. This project is a proactive effort to generate the appropriate tire adhesion test and fatigue monitoring requirements for bias and radial retreaded tires. The purpose of this multi-year project is to complete the update to AC 145-4. Specifically, this project is revising the escalation requirements to provide an updated test procedure for assessing remaining tire strength and an acceptable process for monitoring tire sidewall fatigue in both radial and bias tires. The outcome from this project phase is a validated process for (a) measuring tires adhesion strength in a part number, and (b) determining the safe minimum tread adhesion level that will stop the escalation to the next retread level. The number of times a tire can be retreaded is controlled by an inspection and test system known as the escalation procedure. This procedure is applicable to both bias and radial ply tires and is used to validate that a tire series (defined by part number) can be safely escalated to the next retread level. As part of the escalation procedure provided in the latest revision to AC 145-4, each tire part number must undergo testing to assess the remaining tire strength before the part number can be escalated to the next retread level. This testing must be either tire adhesion testing between the tread and casing structure or interferometric testing. The technical suitability of these competing methods for assessing remaining tire strength is unknown and there is serious disagreement in the tire industry regarding the appropriateness of each approach. Discovery testing was conducted in FY02 to evaluate the suitability of current adhesion testing methods that apply loads normal to the adhesive bond at room temperature. Additionally, micromodulus testing was conducted to determine if there is evidence that bond residue hardening accumulated through multiple retread cycles might be a factor leading to reduced retread adhesive bond strength. The FY02 tire coupon test results will be used to design and conduct tests that will establish the “safe” minimum tread adhesion level for aircraft tires. The outcome from these tests will be a metric or process for establishing safety limits as a function of tire type.

Specialty Metals Processing Consortium

Jim Van Den Avyle
Sandia Labs FAA AANC

The Specialty Metals Processing Consortium (SMPC) is a group of 10 US Specialty Metals producers and aerospace alloys users, working with Sandia National Laboratories, who have formed a consortium to perform joint research in the area of specialty metals production, processing, quality, and performance. This work focuses on improving quality in ingot production of titanium alloys and nickel-based superalloys used in aircraft turbine rotating components. SMPC's goal is to eliminate defects by the continued research, development, and optimization of existing melting processes, and by the evaluation and adaptation of novel and innovative processes when applicable. The program is organized into five task areas: Vacuum Arc Remelting, Electroslag Remelting, Hearth Melting, Process Modeling, and Reporting Anomalies in Superalloy Billet. Contents of these tasks are defined each year by the industrial members through a sequence of workshops and discussions leading to formal project task descriptions. The VAR, Hearth, and ESR tasks include components of advanced controls, diagnostics and characterization, and novel process improvements. Superalloy producers are characterizing types of metallurgical features which cause reported ultrasonic anomalies, and they are collecting frequency of occurrence data for several alloys. The Process Modeling task develops and verifies models of the three processing methods and delivers them to SMPC members. The task areas incorporate strong experimental programs starting in the laboratory, leading to full-scale industrial demonstrations. Heavy emphasis on industrial experiments has been a key to technical progress and eventual implementation on the shop floor.

Completed activities in the Vacuum Arc Remelting task include: 1) development of a VAR furnace process monitor (intelligent load cell filter) and completed preliminary testing on an industrial furnace at Shultz Steel, 2) development of the nine-state advanced VAR controller (AVARC-I, which includes on-line parameter estimation), then installed and demonstrated it on several industrial furnaces, and 3) instrumented VAR experiment melting titanium at Allvac Corp. to support VAR model development. Completed activities in the Electroslag Remelting task include: 1) instrumented ESR experiment melting Alloy 718 at Precision Rolled Products Corp. to support ESR model development, and 2) development of AESRC-1 version of an advanced non-linear ESR furnace controller using laboratory tests and demonstrated it on an industrial furnace at Allvac Corp. Completed activities in the Process Modeling task include: 1) An improved version of the BAR VAR model was released to SMPC members which included a new GUI front end, new data output visualizations, and improved electrical and thermal inputs for titanium melting, 2) An enhanced ESR model was delivered to SMPC members which included full transient capabilities, melt schedule, electromagnetic fluid flow capabilities, and a GUI input front end, and 3) Projects were initiated at Purdue University and the University of Arizona to develop models for predicting solidification defects during ingot solidification. Completed activities in the Nickel-base Superalloys task include: 1) SMPC superalloy producers worked with the FAA and the RISC group to define procedures to report the frequency of occurrence of ultrasonic anomalies found in Alloy 718 and Waspaloy billet material, 2) SMPC members began collecting and reporting data for the anomaly database in the first quarter of 2002, 3) SMPC developed procedures to metallurgically and ultrasonically characterize selected defects found in Alloy 718 and Waspaloy billet product, and 4) SMPC issued a draft report containing information for a recommended melting practice for nickel-base superalloys

Smoke Transport Model to Enhance the Certification Process for Cargo Bay Smoke Detection Systems

Jill Suo-Anttila
Sandia National Laboratories

Current regulations require that aircraft cargo compartment smoke detectors alarm within one minute of the start of a fire and at a time before the fire has substantially decreased the structural integrity of the airplane. Presently in-flight and ground tests, which can be costly and time consuming, are required to demonstrate compliance with the regulations. A physics based Computational Fluid Dynamics (CFD) tool, which couples heat, mass and momentum transfer, has been developed to decrease the time and cost of the certification process by reducing the total number of both in-flight and ground experiments. The tool provides information on smoke transport in cargo compartments under various conditions, therefore allowing optimal experiments to be designed. The CFD based smoke transport model can enhance the certification process by determining worst case locations for fires, optimum placement of fire detector sensors within the cargo compartment, and sensor alarm levels needed to achieve detection within the required certification time. The model is fast running to allow for simulation of numerous fire scenarios in a short period of time. In addition, the model is coupled to a graphical user interface to allow it to be easily used by airframers and airlines that are not expected to be experts in CFD. Full-scale cargo compartment experiments at the FAA Technical Center are in process, which will aid in the validation of the code and will gauge the reliability of using the tool to increase the efficiency of the aircraft fire detection system certification process by decreasing the total number of ground and flight experiments. Following validation of the smoke transport code, it will be released to the intended user community.

Aircraft Wire System Test Bed Development

Mike Dinallo
Sandia Labs AANC

Aircraft wire systems that were surveyed in the *Intrusive Inspection Final Report,* December 2000, and the *Aging Transport Systems Task 1 and 2 Final Report*, August 2000 showed that wire degradation occurs to some degree among various types of commercial passenger aircraft. Consequently, numerous wiring diagnostic techniques have been applied and are under development to inspect and monitor aircraft wire-system condition. This project is developing a test bed capability to characterize and validate aircraft wire-condition monitoring and diagnostic technologies. The test bed will have many representative aircraft wire-system harnesses typically found on intermediate and wide-body passenger aircraft. Both newly fabricated and aged (extracted from retired aircraft) harnesses, with and without naturally occurring and simulated wire defects, will be used in the test bed. The defects will be of different categories and types to allow for different diagnostic methods to accurately and reliably identify and locate particular defect category and type. These wire harnesses are contained within a metallic enclosure, simulating typical aircraft structures, and terminated with connectors or loads. The enclosure is modularly designed to permit future upgrades of the test bed to simulate actual aircraft wiring lengths and other relevant features. The test bed will provide wire defects in field-like conditions that are common to all wire diagnostic technologies and users. The project will occur over a three-year period to allow for realistic attributes of aircraft environment(s) to become part of the test bed development. This time period will provide ample opportunity for industry and other interested organizations to suggest for improvements to the test bed wire-system features and environment.

A database has been developed that documents various publicly attainable wire systems inspection and testing reports, wiring maintenance and installation procedures, and wire specifications for use in fabricating wire harnesses and defects in the test bed. The defect types were, in part, based upon the findings in the reports referenced above. Various wire harness types, from retired aircraft, have also been acquired from Boeing 727, 737, and 747, and from Douglas DC-9 and DC-10 planes. Wire to connector assembly certified personnel are in the process of fabricating new wire harnesses using aircraft and military specified procedures. The test bed enclosure has been designed and delivered and is presently being fitted with wire harness connector terminations. Wiring defects fabrication is under development including written procedures for each defect type. Instrumentation for characterizing the wire harness transmission line parameters has been acquired and procedures for using the instrument have been development.

The first year project will continue to assemble and acquire new and retired wire harness that have naturally occurring and fabricated wire defects. These harnesses will be assemble into the test bed and characterized in-situ to the test bed with regard to transmission line parameters as a quality control and support measure for test bed users. Year two test bed upgrades will include adding aircraft wire system components such as circuit breakers, arc-fault interrupters, powered wire harness capability, longer and branched harness routing, and some degree of aircraft environment conditions such as “grime” and electromagnetic background “noise. “

Non-Structural Systems Risk Assessment and Testing

Paul Werner
Sandia Labs AANC

The operation and maintenance of aircraft systems are constantly changing – often demanding more performance than was originally anticipated. Simultaneously, the aircraft systems age and the technological environment in which they operate changes. Therefore, potential safety concerns may not be evident from service data. To appropriately identify the safety critical aspects of the complex interactions of these systems, systems designs need to be reviewed in light of both current and potential future operating environments, and safety critical system characteristics need to be identified for further study. Overall General Risk and Maintenance Assessment will be accomplished in several phases. Each phase will look closely at a different mechanical system, including but not limited to, Mechanical Systems included in ATA codes 21, 25, 26, 27, 29, 30, 32, 35, 36, and 38. Eventually an aircraft-level risk assessment methodology will be developed. This abstract deals specifically with the aging Flight Control System.

Specific tasks include analysis and review of the design data on Flight Control Systems presented to the FAA for certification for two airplanes, a Boeing 757 and an Airbus A320. This review will include system description, safety analysis, and other documents for the designated system and will identify components that perform a critical function, such as dual load path elements. These are components for which complete failure could result in an unsafe condition or whose latent failure makes subsequent failures critical. Specific flight control assemblies and components will be tested, focusing on dual load path areas. We are currently planning tests on 737, 747, and A300 flight control elements. The tests will study the performance of flight control hardware in the presence of a single element failure. It will also investigate the relationship between fatigue life, damage tolerance, and nondestructive inspection sensitivity.

Lessons Learned

Paul Werner
Sandia Labs AANC

The Aircraft Certification Service is responsible for the safety of civil aircraft. The safety of large transport airplanes operating in commercial service throughout the world has steadily improved over the last several decades. Currently, commercial air travel within the U.S. is the safest form of mass transportation available. Nevertheless, although rare, accidents still occasionally occur. When they do occur, it is important to identify the root causes of these accidents so that appropriate steps may be taken to reduce the risk of their recurrence. A key factor in reducing the risk of reoccurrence is a formal lessons learned process. Integral to the larger lessons learned process is a training component capable of facilitating the development of critical thinking and decision making from an aircraft-level awareness. The lessons learned from all aviation safety information spans several generations of safety managers. It is no longer possible for comprehensive knowledge to be exchanged from experienced safety individuals to the next generation of safety personnel through on-the-job training alone. The system is so complex that it is unlikely any one individual can possess comprehensive system safety understanding. It is necessary to adopt a more rigorous and systematic approach to lessons learned safety training and management.

This project consists of three phases: Phase I – Research, Phase II – Team training development ,and Phase III – Computer-Based Instruction (CBI) development for internet accessible lessons learned training. There is also a related proposal for a formal lessons learned process and database for use by FAA/AIR and industry.

The two main areas benefiting from aviation safety lessons learned are: 1) DESIGN AND CERTIFICATION of future products, and 2) SAFETY OVERSIGHT of in-service products. In the area of design and certification of products, expanded lessons learned knowledge would result in:

- Better understanding of the regulations that resulted from the accidents
- More consistent application of the requirements (i.e., know "why" a requirement exists)
- Better direction to changes of requirements (e.g., new rules, special conditions, equivalent safety findings, etc.) by knowing why the existing requirements are in place
- Potential identification and justification for regulations that do not exist that might be needed.

In the area of safety oversight, Aircraft Certification safety managers required to make critical safety decisions will be better prepared to understand the distinction between safe and unsafe. A formal lessons learned program would serve to aid in the understanding of unsafe designs, conditions, events, and precursors and “when” and “what” actions should be taken.

In the area of aircraft certification, there is currently no formal method to capture and train lessons learned from past accidents. Only those directly involved with the accident investigation or rule change may have the “whole picture,” and accidents and incidents are numerous and too complex to be managed by informal or incomplete lessons learned methods. Often standards, policies, and lessons that result from transport accidents may take ten years or more to develop and implement. Their development and introduction may take longer than the careers of those originally involved, causing valuable lessons learned and critical tribal knowledge to be lost. Also, accident investigation findings may not correctly identify regulatory shortcomings or key lessons learned and revised regulations and policies may not reveal actual failure condition(s) intended to be protected. There are profound and valuable lessons that can be identified and captured today and passed on to the next generation of aviation industry professionals.